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Pre-service teachers' self-concept and views toward using ICT for teaching science

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Abstract

There is an increased demand to empower pre-service teachers (PSTs) with knowledge and skills regarding the use of information and communication technologies (ICTs) for teaching science. Using the technology acceptance model as theoretical lens, this paper explores the self-concept and views of PSTs in their final year of study regarding their competences to teach science with ICTs. A mixed methods design was used to collect data from 506 PSTs in two phases. In the first phase, all participants responded to a technological pedagogical and content knowledge questionnaire. In the second phase, semi-structured interviews were used to collect data from a subsample of 28 participants. Results showed that PSTs still underestimate their competences to teach science with ICTs and the majority believe that different school situations and lack of use of ICTs by mentor teachers contribute to failure to build on their competences. Findings also revealed that PSTs have the highest perceived knowledge in technological pedagogical knowledge (TPK) and lowest in technological knowledge. We suggest that PSTs have opportunities to develop their technological content knowledge (TCK) through self-directed learning for it to be on par with their TPK. A linear relationship in the development of PSTs' TCK and TPK would ensure improved instructional quality in science classrooms. This paper suggests different strategies to build PSTs' independency in the use of ICTs to teach sciences.

Keywords: views, ICT integration, pre-service teachers, science education

INTRODUCTION

Information and communication technology (ICT) resources have increasingly been adopted for use in various industries, including education, health, economics, and manufacturing. For the education sector, there is an increased number of schools adopting ICTs to help teachers and learners in the teaching and learning process (Drozdek et al., 2020; Hoyles, 2018; Mokotjo & Mokhele, 2021; Padayachee, 2017; Petko et al., 2015).

ICT skills are fundamental requirements as many schools are emphasizing that teaching using ICTs is necessary for today's modern learner (Bankole, 2022; Ertmer & Ottenbreit-Leftwich, 2010; Kara, 2021; Mokotjo & Mokhele, 2021; Rubach & Lazarides, 2021). Competence beliefs concerned with elementary ICT skills have been found to be essential for ICT integration (Knezek & Christensen, 2016; Rubach & Lazarides, 2021). This has caused the use of ICTs in teaching to be one of the ways of enhancing the quality and effective teaching of science (Smith et al., 2016; Taimalu & Luik, 2019). For instance, research has established that teaching with ICTs helps learners develop positive attitudes and beliefs toward learning science as it ensures deep understanding of concepts (Drijvers et al., 2016; Harju et al., 2019). Despite overwhelming evidence from previous studies about the importance of ICT in teaching, it has not been fully utilized in classrooms (Cheok et al., 2016; Martin, 2018; Taimalu & Luik, 2019).

This inadequate use of ICT has attracted a variety of explanations. It has been partly associated with teachers' insufficient knowledge vis-à-vis technological knowledge (TK), technological content knowledge (TCK), and technological pedagogical knowledge (TPK), which are regarded crucial in teaching with ICT (Gudmundsdottir & Hatlevik, 2018; Marbán & Sintema, 2021; Nikolopoulou & Gialamas, 2015; Qui et al., 2022; Tondeur et al., 2018). Based on Mishra and Koehler's

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Contribution to the literature

- The paper focuses on pre-service teachers' knowledge and views about using information and communication technology (ICT) to teach sciences during teaching practice. The paper highlights the importance of technological content knowledge (TCK) and technological pedagogical knowledge (TPK) in pre-service teachers' use of ICT for teaching science
- Findings revealed unbalanced TPK and TCK knowledge with high TPK recorded.
- The paper suggests that a balanced TCK and TPK development would help pre-service teachers improve instructional quality in science classrooms during teaching practice. This paper further suggests different strategies to build pre-service teachers' independency in the use of ICTs to teach sciences

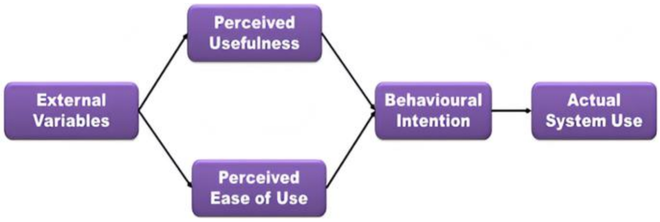

Figure 1. TAM (Venkatesh & Davis, 1996, p. 453)

(2006) conceptualization, TK is basically teachers' knowledge of identifying ICT tools that support teaching, while TPK refers to the innovative mix of teachers' knowledge of selection and use of appropriate educational technologies for supporting teaching strategies and approaches. TCK, then, basically refers to teachers' knowledge of teaching (science) concepts using suitable educational technologies. Thus, in helping PSTs develop their knowledge about teaching with ICT, emphasis has been placed on the balanced development of their TCK and TPK (Choi & Paik, 2021) as these are directly related to classroom activities. This lack of balance in PSTs' TK, TCK, and TPK is evident in this and several prior studies and remains an area of concern for research.

Apart from inadequate knowledge of TK, TCK, and TPK, low levels of teacher use of ICT have been associated with self-efficacy beliefs held by teachers and the historical influence of teaching methods that promote teacher-centered approaches (Atasoy et al., 2015; Avci & Coskuntuncel, 2019). Research has further revealed that pedagogical and self-efficacy beliefs are among the most important factors that influence teachers' acceptance, adoption, and integration of ICTs in their instructional practices (Ertmer, 2005; Ertmer & Ottenbreit-Leftwich, 2010; Taimalu & Luik, 2019; Vekli, 2021). This implies that teachers who believe in their abilities to use technology are more likely to explore different ICT resources that can help them improve the quality of their teaching. This may not be the case for those that have negative views about technology.

The purpose of this paper was to investigate the influence of PSTs' self-concept and views about ICTs on their acceptance, adoption, and usage of ICTs in classroom instruction. Several studies have focused on the importance of technology in education. However, little research has been conducted on PSTs' self-concept and views about using ICTs for teaching science. This agrees with the view of Yesilyurt et al. (2016) that there is currently limited research focusing on pre- and in-service teachers' self-efficacy beliefs about the integration of ICTs in classroom instruction. This study will contribute toward filling this gap in knowledge by highlighting PSTs' self-concept clusters based on their TK, TCK, and TPK. It will also contribute to instructional practice by promoting the development of teachers' views and knowledge about teaching science using ICTs. Furthermore, it will contribute by way of informing teacher education providers on which areas they should focus on to improve PSTs' knowledge about ICTs. It is also hoped that the findings will influence policymakers to enact educational polices anchored in technology-enriched instructional strategies in schools. To address this purpose, this study posed two questions whose answers are contained in the results and provide insight about PSTs' self-concept and views.

1. What kind of clusters about PSTs' self-concept can be formed based on their TK, TCK, and TPK characteristics?
2. What are PSTs' views about their experiences with ICTs for teaching science?

Theoretical Framework

The study used the technology acceptance model (TAM) as theoretical framework for examining and explaining PSTs' views about using ICTs in teaching science (**Figure 1**). According to Lai and Bower (2019), self-efficacy beliefs contribute largely to teachers' intentions to use ICT in teaching. The TAM as a theoretical framework has been used widely to study teachers' acceptance and usage of technology in their instructional practices (Ensminger, 2016; Lala, 2014; Perienen, 2020). The TAM was first conceptualized by Davis et al. (1989) on the basis of perceived usefulness, perceived ease of use, and attitude toward usage of technology in education. Davis et al. (1989) posited that "*behavioral intention to use*" is a significant factor in predicting a teacher's use of technology.

Some researchers have used the TAM to examine the perceived usefulness and perceived ease of use of interactive instructional resources (Gorhan & Oncu,

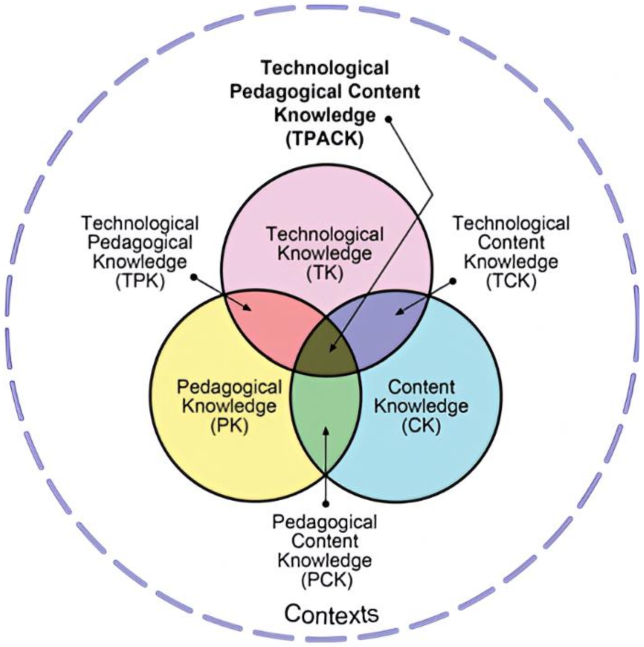

Figure 2. Knowledge types that interact to form TPACK (Koehler & Mishra, 2009, p. 63)

2015; Menzi et al., 2012). In this study, we used the model to examine and explain how PSTs' perceived usefulness and perceived ease of use of ICT influenced their abilities to use technology in teaching science. While the majority of previous studies have largely focused on investigating factors that affect PSTs' use of ICTs, few have exclusively studied PSTs' views about their abilities to use ICTs to teach science. This study will contribute valuable knowledge about PSTs' views regarding ICT usage in teaching.

LITERATURE REVIEW

Pre-Service Teachers' TK, TCK, and TPK

For over a decade, the technological pedagogical and content knowledge (TPACK) framework (Mishra & Koehler, 2006) has been at the center of research concerned with the integration of educational technologies in classrooms. It emanated from Shulman's (1986) pedagogical content knowledge (PCK) framework, which was conceptualized as an amalgam of pedagogical and subject matter knowledge. Mishra and Koehler (2006) introduced TK as an important addition to PCK considering the high rate at which technology was being used in sectors other than education. They argued that technology would help teachers improve the quality of instruction and bring in visualization of concepts through videos and pictures to enhance understanding.

To study PSTs' knowledge of ICT, we used some aspects of TPACK. TPACK is basically a combination of three major knowledge types: TK, pedagogical knowledge (PK), and content knowledge (CK). The interplay of these knowledge domains gives rise to important subdomains: PCK, TCK, TPK, and at the heart of the framework, TPACK, as can be seen from the visual conceptualization in **Figure 2**. While all TPACK knowledge subtypes are important for studying teacher knowledge of educational technologies, this study focuses on TK, TCK, and TPK to analyze PSTs' knowledge for using ICTs to teach science. Thus, we focus on the abovementioned knowledge domains, and refer the reader to Mishra and Koehler (2006) for deep insight into the knowledge domains not discussed in this study.

The choice of TK, TCK, and TPK for examining PSTs' knowledge of teaching science with ICTs in the current study was underpinned by the following conceptual understanding. TPK mirrors the instructional use of ICT in education (Andreasen et al., 2022; Mishra & Koehler, 2006), TCK reflects teachers' competences to select suitable ICT resources for teaching science (Mishra & Koehler, 2006), and TK illuminates the individual's knowledge about different ICT resources that can be used for educational purposes. This multifaceted knowledge base supports PSTs' ICT integration in classrooms (Schmidt et al., 2009).

Additionally, it has been observed that PSTs whose TPK is well developed have high potential to teach with ICTs and to handle ICT resources with confidence (Maeng et al., 2013). Otherwise, PSTs' low confidence and inadequately developed ICT competences have been found to account for their low level of ICT integration in classrooms (Gudmundsdottir & Hatlevik, 2018; Nikolopoulou & Gialamas, 2015; Tondeur et al., 2018).

Research has produced mixed findings about PSTs' TK, TCK, and TPK (Mourlam et al., 2021; Putri et al., 2021; Qui et al., 2022; Uerz et al., 2018). It has been found that teachers have exhibited challenges in differentiating between TCK and TPK (Qui et al., 2022), with low TPK being reported in some cases where online and microteaching approaches have been used (Putri et al., 2021). Notwithstanding these challenges, Mourlam et al. (2021) and Srisawasdi et al. (2018) reported positive development of PTSs' TK, TCK, and TPK. For example, PSTs recorded significant positive changes in their TCK and TPK in the way they implemented their ICT knowledge into their lesson planning after undergoing a technology-oriented short course (Mourlam et al., 2021). Similarly, in online and microteaching activities related to mobile technology integration in teaching, PSTs showed high levels of TK, TCK, and TPK (Srisawasdi et al., 2018). The challenges PSTs have experienced with their TK, TCK, and TPK development need to be addressed for them to develop into individuals who can use ICT resources effectively.

To mitigate challenges facing PSTs' knowledge development about TK, TCK, and TPK, recommendations have proposed revision of teacher training programs to include educational modules that would focus on supporting PSTs' development of their TK, TCK, and TPK. Enhancing these knowledge domains during training would help balance their TCK and TPK development. This would help reduce or eradicate factors that may be hindering their overall development of TPACK (Choi & Paik, 2021). Considering that ICT tools used for teaching and learning purposes, it has been argued that developing more research instruments that would focus on domain-specific ICT issues can increase research outputs related to TK, TCK, and TPK about science education and science, technology, engineering, and mathematics (STEM) education in general (Syukri et al., 2020).

Pre-Service Teachers' Views About ICT

In general, teacher beliefs play a very important role in the pedagogical choices and decisions teachers make, and their views about ICT integration determine whether they would use ICTs in their classrooms or not (Ertmer, 2005; Ertmer & Ottenbreit-Leftwich, 2010; Taimalu & Luik, 2019). Considered as personal truths which are highly subjective, beliefs are based on an individual's personal evaluation and judgement of what is true and pedagogically valuable.

With regard to using ICTs in instruction, teachers' views influence their perception of the role and educational value of ICTs in the teaching and learning process (Goos & Bennison, 2008). Their self-efficacy beliefs serve as indicators of how confident they are in using ICT tools for teaching and in recognizing their own capabilities in effectively choosing and appropriately using ICTs (Bandura, 1999). To this effect, studies have revealed that PSTs' self-efficacy beliefs about adoption and use of ICTs in teaching can be enhanced by increased access and use of ICT tools (Abbitt & Klett, 2007; Al-Awidi & Alghazo, 2012; Arslan, 2012). This means that when PSTs have increased opportunities to access ICT resources at university, they will be more likely to use it during their teaching practice and in their future practice.

Studies have reported that teachers with low self-efficacy beliefs about ICTs are not eager to use it for teaching (Moore-Hayes, 2011). In some cases, teachers with positive pedagogical beliefs toward ICTs rarely use it in their practice (Ertmer et al., 2012). PSTs who show interest in ICTs and value their educational usefulness have been found to integrate ICTs in their teaching more than those that do not (Caner & Aydin, 2021; Cheng et al., 2021). In addition, perceived usefulness of ICT resources is regarded a good predictor of ICT integration in classroom instruction (Cheng et al., 2021). Where PSTs' views about the use of ICTs have been sought, the majority indicated their eagerness to use ICTs in their classrooms but emphasized the need to combine it with concrete objects for effective teaching (Sahal & Ozdemir, 2020). This is because integration of ICTs is by no means a replacement of concrete objects. In situations where PSTs feel that learners need to see actual objects, they should be encouraged to use them.

Salleh et al. (2021) postulated that self-efficacy and perceived usefulness contribute significantly to PSTs' use of ICTs, and thus it is also helpful to involve PSTs in professional development programs during their teaching practice. This is because such programs have been seen to enhance teacher self-efficacy toward ICT integration and level of confidence in their ICT skills (Hall & Trespalacios, 2019). This is because an increase in technology-enriched professional development programs would be helpful in enhancing PSTs' knowledge and views about ICTs and their use in teaching (Salleh et al., 2021). Agreeing with this view, Abbitt (2011) pointed out that self-efficacy beliefs and knowledge about ICTs are crucial for teaching with technology.

Moreover, Palak and Walls (2009) posited that for professional development programs to be responsive to the need for ICT integration in instructional practices, they need to be tailored to emphasize student-centered ICT-supported pedagogy. Thus, through professional development programs, PSTs would develop ICT competence and the necessary experience for teaching with technology. Teaching experience cannot be overlooked when discussing technology integration in the classroom, because it has a great influence on PSTs' self-efficacy beliefs about teaching with ICTs (Al-Awidi & Alghazo, 2012). This helps PSTs to enhance their technological competence, which is important in explaining their use of ICTs in instruction (Birisci & Kul, 2019; Keser et al., 2015). However, any effort to support teachers' quest to teach with ICTs cannot yield positive results without teachers' own intention to attain the required knowledge. To this effect, Karakis (2022) pointed out that PSTs' intentions to use ICTs is directly influenced by their interest in instructional technologies and ICT-integration self-efficacy.

Some studies have showed that class size also has a great influence on teachers' integration of ICTs (Farjon et al., 2019; Ifinedo et al., 2020). Despite this and other factors, PSTs can be supported in their quest to gain knowledge about ICT integration. For example, design practice and self-directed learning can be very helpful in developing PSTs' self-efficacy and knowledge about ICT integration (Bakac, 2018; Moon et al., 2021). In their study aimed at understanding PSTs' technology-integration views, Moon et al. (2021) reported that through design practice, PSTs' views on ICT-integration were improved. Bakac (2018) revealed that self-directed learning among PSTs has been found to promote positive ICT-integration self-efficacy beliefs.

Table 1. Knowledge domains, sample items, and Likert scale of part of the TPACK survey

Knowledge domain and sample items	Likert scale				
	SA	A	N	D	SD
TK					
I can learn technologies easily.					
I am aware which ones of the technologies would work better for my science teaching.					
TCK					
I know how to teach science using digital boards, e.g., Smartboard, digital projector.					
I know how to teach science using learning management systems, e.g., Moodle, Blackboard.					
TPK					
I am able to choose technologies that enhance my teaching approaches for a lesson.					
I am able to choose technologies that enhance students' learning for a lesson.					

Note. SA: Strongly agree; A: Agree; N: neutral; D: Disagree; & SD: Strongly disagree

METHODOLOGY

The current study drew on a sequential explanatory mixed methods research design to investigate PSTs' knowledge and views about teaching science using ICTs (Creswell & Plano Clark, 2017; Yin, 2011). This two-phase design allows the researcher to first administer a survey for quantitative data collection and analysis. This is followed by the second (qualitative) phase, where a small sample is drawn from among the subjects who participated in the quantitative phase for qualitative data collection and analysis. The two phases allow for a deeper understanding of the research problem. A TPACK survey was used to collect quantitative data about PSTs' TK, TCK, and TPK, while semi-structured interviews enabled us to gather qualitative data about their ICT views. Data from the survey provided insight about PSTs' self-perceived knowledge about teaching with ICTs. In addition, verbatim quotes from the face-to-face semi-structured interviews ensured that the participants' own words were used to produce rich and thick descriptions of their views about teaching with ICTs (Creswell & Plano Clark, 2017; Gikas & Grant, 2013; Merriam, 1998).

Participants and Context

This study was aimed at gaining insight into PSTs' knowledge and views about their competences to teach science using ICTs. We recruited 506 participants from three Southern African Development Community (SADC) countries–Lesotho, South Africa, and Zimbabwe. These were final year university students who were purposively selected to fit the study. All 506 PSTs participated in the quantitative phase of the study, with 28 further selected purposively to take part in interviews. The selection criteria for interview participants included

(1) one must have participated in the quantitative phase of the study,

(2) at least seven participants were drawn from each of the three countries Lesotho, South Africa, and Zimbabwe, and

(3) one must be willing to participate in the interview.

All participants had completed their teaching practice in their respective countries prior to taking part in the study. They were made aware of the purpose of the study as well as the need for them to participate voluntarily. They were also informed that they had the right to withdraw from the study at any point without any obligation to state the reason for their withdrawal.

Data Collection

A TPACK survey by Schmidt et al. (2009) was adapted and modified to fit the purpose of the current study. The modified version of the survey comprised 48 items which were distributed across 10 subfactors. Of the subfactors, only three–TK, TCK, and TPK–were considered for investigation in this study. Internal consistency of the original scale was calculated by the developers and found to be 0.96. Using our sample, internal consistency of the whole scale and its subfactors was also calculated to establish its reliability for collecting data. Internal consistency for the whole scale was found to be 0.87 and subfactors TK, TCK, and TPK had internal consistencies of 0.84, 0.81, and 0.71, respectively. This implies that the instrument was reliable for data collection for this study. Internal consistency for all TPACK subfactors was within the acceptable range. However, in this paper, we have chosen to report the internal consistency of only three subfactors because they are the focus of the current study. Participants were asked to rate their level of agreement with positively worded statements on a five-point Likert scale ranging from 1=strongly disagree to 5=strongly agree. Sample statements from the TPACK survey are shown in **Table 1**.

A semi-structured interview protocol was used to collect data from a subsample of 28 PSTs related to their views about teaching with ICTs. The interviews were appropriate for gaining an in-depth understanding of PSTs' views about teaching with ICTs and their classroom experiences when they used ICT resources (Creswell & Plano Clark, 2017). The duration of each interview was 60 minutes, in which four main questions were used to probe participants in relation to their views about teaching with ICTs, and their experiences while

Table 2. Participants' self-concept profiles per cluster

Cluster	Cluster size	TK	TCK	TPK
1	78 (15.4%)	3.45 (.62)	2.48 (.59)	3.07 (.57)
2	209 (41.3%)	3.87 (.45)	3.35 (.44)	3.88 (.34)
3	219 (43.3%)	4.33 (.40)	4.14 (.38)	4.36 (.43)

using ICT tools (Gikas & Grant, 2013). Transcribing of all the interviews preceded a comprehensive data analysis process.

Data Analysis

To gain insight into PSTs' knowledge characteristics about teaching with ICTs, a triangulation of quantitative with qualitative analysis techniques characterized the data analysis process. Quantitative data were analyzed using statistical package for social sciences version 23 (SPSS 23), whereas qualitative data were analyzed using thematic analysis. To accomplish the purpose of the study, a k-means cluster analysis procedure was performed. This produced three clusters of PST knowledge based on their TK, TCK, and TPK.

Cluster analysis is a robust multivariate analysis technique for minimizing biases and estimation errors when calculating descriptive statistics of a heterogeneous group, such as the sample for the current study (Kayri, 2007). This quantitative grouping technique minimizes analysis bias by creating homogeneous subgroups. Participants with similar characteristics are grouped together in the same group, and those with different characteristics will belong to different groups. For this study, we used cluster analysis to divide our sample into groups of participants with similar TK, TCK, and TPK characteristics. We then proceeded to compute means and standard deviations of participants' scores in these subgroups (**Table 2**).

For a long time, cluster analysis has been a useful technique in educational research for profiling student and teacher characteristics based on different variables (Blashfield & Aldenderfer, 1978; Egan, 1984; Shavelson, 1979). The technique is still prominent in recent educational studies as one of the preferred grouping data analysis procedures (An et al., 2022; Gonzálvez et al., 2018; Larkin & Milford, 2018). We thus carefully selected it for this study to investigate PSTs' knowledge about teaching science with ICTs. To analyze the interview data, we went through the process of thematic analysis, which is one of the recommended techniques for analyzing qualitative data (Creswell & Plano Clark, 2017). The analysis process involved a two-stage process where the two researchers separately identified themes that emerged from the data before proceeding with creation of codes, paying particular attention to participants' voices in the interviews (Saldaña, 2021). We both have sufficient experience handling and analyzing qualitative data, with one of us bringing 10 years of qualitative research experience to the team. We then reviewed the codes together. Codes on which we did not agree were either removed and replaced or were merged.

Trustworthiness and Rigor of the Study

The quality, worth, and merit of this study was established by assessment of its trustworthiness and rigor as guided by several authorities (Creswell & Plano Clark, 2017; Henry, 2015; Krefting, 1991; Lincoln & Guba, 1985). To ensure trustworthiness and rigor of the study, we employed peer debriefing and member checking and presented direct quotes, as well as made rich and thick descriptions of the data from the participants (Creswell & Plano Clark, 2017; Lincoln & Guba, 1985; Merriam, 1998). With regard to peer debriefing, a senior researcher and lecturer at a public university in South Africa was requested to review the interview transcripts, themes that emerged from the data, and all the codes that emerged from the coding process (Lincoln & Guba, 1985). This researcher has many years of experience with conducting qualitative research and her research is largely focused on science teacher education. The researchers agreed on the majority of the themes and codes. The themes and codes which had disagreements were removed. In establishing rigor, we provide rich and thick descriptions of the data supported by direct quotes from participants (Merriam, 1998). For member checking (Creswell & Plano Clark, 2017), participants were allowed to review the interview transcripts and verify that their views were correctly represented.

RESULTS

This section presents results related to participant responses to the survey and semi-structured interviews regarding their self-concept and views about the use of ICTs in science instruction. The first part of this section shows results for the participants' self-concept. This is followed by findings about their views. Results related to participants' views were organized using tables showing a summary of themes that emerged from content analysis of the interview transcripts and codes for each theme. The frequencies of each code are also provided. Each table is then accompanied by an elaborate presentation of participants' views supported by verbatim quotations by the participants.

Clusters of Participants' Self-Concept About Teaching Science with ICTs

To understand participants' self-concept about teaching with ICTs, a k-means cluster analysis was

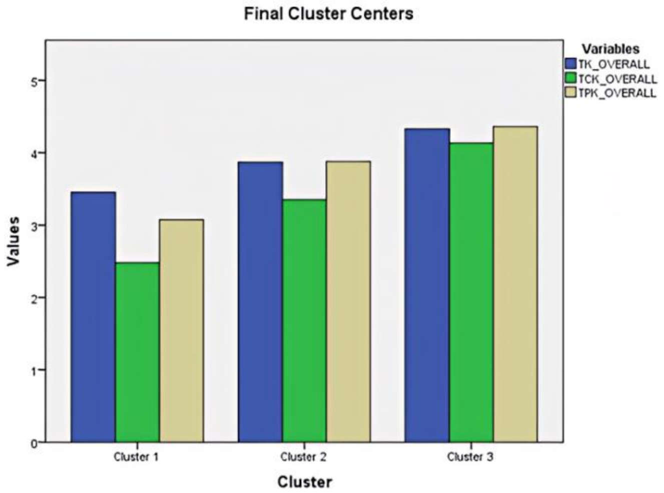

Figure 3. Visual representation of participants' self-concept profiles

performed which produced three clusters of participants based on their self-perceived knowledge of teaching with ICTs. Detailed descriptions relating to the self-concept of members of each cluster are presented in **Table 2**.

Examining **Table 2**, three clusters were created that grouped participants based on their mean scores for each knowledge dimension. Cluster 3 was the largest cluster, with 43.3% of the total participants, while cluster 1 was the smallest, with 15.4%. The information in **Table 2** shows that the majority of participants exhibited mean scores greater than three in TK, TCK, and TPK as evidenced by the cluster sizes. **Table 2** further shows that PSTs in cluster 3 reported the highest TK, TCK, and TPK mean scores compared to those in clusters 1 and 2. This can be seen from a visual representation of the clusters (**Figure 3**).

Cluster 3 had the highest mean scores for TK, TCK, and TPK, with 4.33, 4.14, and 4.36, respectively. This implies that participants from this cluster are more likely to exhibit higher knowledge of selecting instructional strategies that support the use of ICTs in classrooms than their colleagues in clusters 1 and 2. They are also more likely to choose suitable instructional technologies for teaching specific science subject matter than their counterparts in the other clusters. We also found that 15.4% of the participants would face challenges in selecting suitable ICT tools for the effective teaching of science. The overall distribution of the scores shows that the participants will encounter challenges in teaching with technology. This can be seen from the lack of balance between their TK, TCK, and TPK (**Figure 3**). For example, TK is concerned with their awareness of different ICT resources they can use to teach science, yet this is the knowledge domain with the lowest scores. This would generally cause challenges in their teaching. Based on PSTs' self-concept, researchers proceeded to collect participants' views.

An analysis of variance (ANOVA) was generated together with the final cluster centers for the purpose of showing the contribution of each knowledge dimension to the formation of clusters (**Table 3**). The F test results displayed in **Table 3** were used only for descriptive purposes, because the clusters were chosen to maximize the differences among cases in different clusters. The observed significance levels were not to compare mean differences in PSTs' self-concept about TK, TCK, and TPK, and thus could not be interpreted as tests of the hypothesis that the cluster means are equal. It can be observed from the table that the difference in knowledge between all clusters was statistically significant. This implies that TK, TCK, and TPK significantly contributed to the formation of clusters of participants' self-concept about teaching with ICTs.

Participants' Views About Pursuing the Use of ICTs for Teaching Science

The data on participants' views regarding their pursuit of ICT use for teaching science resulted in four themes (**Table 4**). Three of these concerned the development of learners' cognitive, affective, and psychomotor skills, respectively. The fourth theme that emerged from the data was concerned with classroom discourse and, as such, we called it "teaching and learning process".

All participants that responded to the question related to pursuing ICT for teaching science indicated that they would use ICTs in their lessons because it saves time and reduces the use of the chalkboard. Participants believed that in fostering the development of cognitive skills, ICT would stimulate critical thinking in learners, thereby enhancing understanding of science concepts. By visualizing concepts learned in class using ICT tools, learners create and build their own knowledge. Participants also believed that ICT would help foster learners' development of affective skills. Through watching videos and viewing pictures related to the concepts being taught in class, ICT would stimulate learners' interest in learning the subject and would motivate them to attend lessons regularly. Regular attendance of class helps learners connect concepts taught on different days. In the interviews, participants shared their experiences to support their views about pursuing use of ICTs for teaching science. One participant whose views indicated low CK (Kutluca & Mercan, 2022) and TCK for integration of ICT by admitting that in some instances in class s/he did not know how to pose useful questions to students said:

> "I will love to use ICTs. For example, when I was doing my practical teaching, we had everything. As a math teacher, I did not struggle to use the ICTs provided because every subject I teach you can find on the internet. So, I would download and add certain information or elaborate more on

Table 3. ANOVA test for the clustering of participants based on the knowledge dimension

Knowledge dimension	Cluster		Error		F	Sig.
	Mean square	df	Mean square	df		
TK	25.27	2	.21	503	119.88	.000
TCK	86.36	2	.19	503	447.85	.000
TPK	48.93	2	.18	503	270.15	.000

Table 4. Participants' views about pursuing the use of ICTs for teaching science

Theme	Code	Count
ICT fosters development of cognitive skills	ICT stimulates learners' critical thinking during learning	25
	ICT enhances learning	19
	ICT promotes visual learning	21
	ICT builds knowledge	11
	ICT enhances understanding of concepts	16
ICT fosters development of affective skills	ICT stimulates learners' interest in learning	27
	ICT motivates learners	13
	ICT promotes (visual) learning by seeing	21
	ICT makes learning entertaining	6
ICT fosters development of psychomotor skills	ICT promotes learning by touching (manipulation)	18
	ICT promotes hands-on interactive activities	12
Teaching and learning process	Use of ICT helps to save time	9
	Use of ICT promotes active participation of learners	21
	ICT helps reduce the use of the chalkboard	7
	ICT helps teachers to elaborate information	18

> the information for learners in class using smartboards and the projector. When I went to do my practical teaching last year, I taught physics; normally, learners found the subject physic abstract. Therefore, I would use educational videos from YouTube for them and let them watch them at the math labs. Fortunately, there is enough internet access for everyone, and learners can download educational lecture video for themselves. In addition, the internet provides ample examples to solve different questions. At times, I would use quizzes from the internet regarding the relevant topic and ask learners to answer them in class. When we were dealing with the topic of potential and kinetic energy, I did not know how to ask learners questions regarding the topic, so I divided them in groups of 10 and gave them quizzes from the Internet."

ICT promotes involvement of learners in hands-on activities as they are required to handle and manipulate ICT tools at their disposal in the classroom. Concerning this, participants believed that ICT would help to foster learners' psychomotor skills. With regard to the teaching and learning process, the majority of participants were of the view that instead of drawing a diagram for learners on the chalkboard, a teacher can easily use a projector to display a picture which would be accurate, colorful, and appealing to the eye of the learner. This would save the time used to draw it on the chalkboard. The participants also contented that ICT would help to activate the three important senses for effective audio-visual learning, namely sight, hearing, and touch. Furthermore, the use of ICTs would encourage active participation of learners in classroom activities. One of the participants said:

> "The use of technology is good, because it saves time and the [teacher does not necessarily] need to use the chalkboard … learners understand better when they see what they are being taught instead of just reading … I prefer to involve learners much more. There are those learners who learn by seeing; there are those learners who learn by hearing. Teaching using ICT tools benefits both learners because they get to hear and see what they are being taught. Therefore, I would use ICT to make sure that the learners' learning styles are met, especially auditory, visual, and kinesthetic."

Participants' Views About Teaching Science Using ICTs Versus Traditional Teacher-Talk

Interview participants were asked to rate their views about teaching with ICT compared to traditional teacher-talk (**Table 5**) and to provide justifications for the given ratings.

Table 5 shows that participants highly rated teaching with ICT, with ratings of at least seven out of 10. It can also be seen from the table that majority of participants rated traditional teacher-talk at six or less out of 10. Not all participants provided ratings when responding to this question. Several of them instead opted to offer their opinions about their preferred type of teaching.

The participants who highly rated teaching with ICTs explained that in this era, technology is widely used by

Table 5. Participants' ratings for the quality of teaching with ICTs compared to traditional teacher-talk?

Type of teaching	Rating out of 10	Count
Teaching with ICT	10	5
	9	5
	8	5
	7	7
	≤6	0
Traditional teacher-talk	10	0
	9	0
	8	0
	7	2
	≤6	8

many young children of school-going age. As such, they would easily adapt to learning using ICTs. The participants emphasized that ICT encourages learner-centered instruction, where learners directly engage with the subject matter and with each other. Learners are motivated to explore science using ICT resources, especially when the internet is readily available. One of the participants said:

> "In the ICT class, learners get to engage with one another and ask questions in class, and [this] allows them to learn from one another, whereas the traditional-talk forces the education system/setting to be teacher centered. Learners get bored and lose interest or concentration when they are just sitting there listening to the teacher feeding them with information."

Another participant explained that at his university he was taught how to use ICTs in class and found it progressive to teach with ICTs during teaching practice. He further recounted how one of the senior teachers at the school where he did his teaching practice effectively used ICTs in a chemistry class. He said:

> "At university we are being taught and prepared to teach using slides and projectors in class. I am not used to writing on the board. I am more familiar with preparing slides and presenting them in class. I believe the use of ICT is more effective. I saw in the Chemistry Department how one of the old teachers used an overhead projector and he was brilliant. So, it depends on who is using what and how they can use it."

While the ratings showed that the majority of participants preferred the use of ICTs for quality teaching of science compared to traditional teacher-talk, some also felt that the two can be used to complement each other for effective teaching. One of the participants said that:

> "To be honest, there are good teachers who teach with traditional method. It is pointless if you teach with ICTs, but your content is lacking, because learning will not be effective. It really depends on your knowledge as the teacher because [ICT] resources are just there to guide you."

This participant gave a rating of seven out of 10 to teaching using ICTs and six out of 10 to traditional teacher-talk. The rating and opinion of this participant imply that they believed that teacher knowledge about ICTs and their use is fundamental for effective teaching to occur. Furthermore, despite slightly favoring teaching with ICTs, the participant believed that the two are important to the teaching and learning process. This view is consistent with that of another participant, who said that:

> "You know, it is a 50/50 thing, but I strongly feel like ICT plays a huge role in the teaching and learning environment … The teacher should use both traditional and ICT; not only the traditional method where they just read to the learners what happens, and they expect the learners to understand. They should also use videos to help learners understand, because as I said before, some learners learn by seeing things, some learners even learn by doing things practically."

Participants' Views About Challenges in Using ICTs for Teaching Science

Participants highlighted several challenges they would face when teaching with ICTs. Their views about potential challenges regarding teaching with ICTs were summarized in terms of class management, learners' prior knowledge about ICTs, teachers' knowledge about selecting appropriate ICTs, and internet access and electricity (**Table 6**).

Regarding class management, participants generally believed that using mobile ICT devices such as smartphones during the teaching and learning process would trigger excitement which may lead to uncontrollable behavior among learners. One of the participants said:

> "Okay, the biggest challenge that we would encounter is that maybe when you are using ICT, sometimes you fail to control the class. Let's say you allow learners to use smartphones to search for a certain word or concept, some learners may open other irrelevant sites instead of what the teacher has instructed them to do. In that way, it is going to be very hard to control such a class."

Participants also talked about potential challenges related to learners' prior knowledge about ICTs and teachers' knowledge about selection and use of different ICT tools. They said that learners come to school with no exposure to computers. Learners in schools, in general, lack basic ICT knowledge. This would make it difficult for teachers to use ICTs because they first need to teach

Table 6. Participants' views about challenges in using ICTs for teaching science

Theme	Code	Count
Class management	A teacher can lose control of the class	7
	Learners can target irrelevant material online	16
Learners' prior ICT knowledge	Learners in schools lack basic ICT knowledge	19
	Learners not exposed to computers	11
Teachers' knowledge about different ICT resources	Using ICT resources other than video	9
	Challenges teaching science with ICTs	3
	Choosing the appropriate ICT tool to use	7
	Choosing appropriate content for grade level	4
	Preparation of PowerPoint slides	8
Electricity and the Internet	Unreliable electricity supply	24
	Rural schools have limited internet access	7
	Some town schools have limited internet access	14
	Internet is expensive	21
	Intermittent internet connectivity	19

learners how to handle and use ICT tools before using it to teach science. Participants also contended that as teachers, they would have challenges selecting appropriate ICT tools for teaching specific topics such as trigonometry and functions, as well as packaging downloaded content according to the cognitive level of their learners. They would also have challenges preparing PowerPoint slides for use in class. One participant said:

> "The challenges would be using other ICT methods than videos. The challenge is finding materials in terms of choosing exactly which material to use. For example, if I am using PowerPoint slides, I can prepare my own slides, but if I want to add videos and models to it then it will become more challenging."

Another participant, whose challenges would border on packaging content according to grade level and cognitive level of learners, said:

> "I may be addressing a certain topic, but the explanation of it would be broad with ICT. For example, the internet can give you work on the heart for university first year level; meanwhile, you are searching for content to teach Grade 8 secondary school learners. It requires the teacher to have analytical skills to compile a productive and meaningful lesson plan."

Another prominent view was concerning electricity and internet. Participants said rural areas had little and in some cases no electricity supply, while internet access and connectivity were very poor. This would cause challenges when using ICTs to teach science. In urban schools, electricity supply was also a challenge, while some participants encountered poor internet connectivity and expensive internet costs. One participant said:

> "The biggest challenge with using ICTs is that they require electricity. You need to have electricity to teach with ICT. Unfortunately, electricity supply is not predictable and reliable. The internet is also a challenge, because if it is down, then I will have to go back to the traditional method of teaching."

Participants' Views About Experiences with the Use of ICTs for Teaching Science

Participants' views about their experiences with ICT resources revealed various challenges encountered in using them. ICT resources that were largely used included YouTube videos, overhead projectors, BlackBoard software, Microsoft PowerPoint, Microsoft Excel, Microscope, Visual Lab, Math24 mobile app, and laptops. Many of the participants said that they had challenges operating these ICT tools, which included connectivity issues. In sharing her challenge, one participant said:

> "I used PowerPoint for presentations. I also used Microsoft Word and Excel. Excel gave me challenges because there is a point where you must do addition and use formulas. They are difficult to use and create. Excel has a lot of challenges and I think that I need more training on that. My favorite is PowerPoint because of the animations."

This participant was so positive about using PowerPoint because it enabled her to create content and apply animations to make it attractive to the learners. She also cited lack of training as the reason she had challenges with using Microsoft Excel. One participant faced challenges and frustration while using a projector:

> "I used a projector and computer. The projector is the hardest one because connections are hard. You get into the class and equipment isn't working or is broken down, then you get stressed. In terms of

cellphones, I won't allow cellphones to be used in my class because they can be used inappropriately."

DISCUSSION

The purpose of this study was to investigate PSTs' self-concept and views about teaching with ICTs and how their knowledge influenced their ICT integration. This was done by first profiling participants' knowledge characteristics by creating clusters based on their TK, TCK, and TPK and then analyzing their views.

Results of the cluster analysis revealed that majority of participants possessed adequate knowledge of selecting suitable pedagogical strategies to teach with ICTs as well as selecting appropriate ICT resources for teaching specific science concepts. This was shown in the mean scores recorded for TCK and TPK for participants in cluster 3. This agrees with the view of Cheng et al. (2013) about enhancing PSTs' TPK using digital technologies for effective and quality teaching. TPK attained the highest mean scores across all clusters and TK the lowest. It is expected that there should be a match between TK, TCK, and PCK, but this was not the case for the current study. This lack of parity implies challenges they are likely to face in teaching with ICTs. A similar observation between PSTs' TCK and TPK was observed in a previous study (Choi & Paik, 2021). Choi and Paik (2021) emphasized the need for teacher educators to develop programs that would help PSTs develop balanced TCK and TPK. This is consistent with Baier and Kunter (2020), who emphasized using TPK to study teachers' TPK for quality teaching. In doing this, PSTs will be confident about their ICT competences and will be likely to promote learner-centered instructional approaches in their classrooms. These mean scores could suggest that participants were exposed to ICT tools within and outside the university. It is likely that they interacted with digital devices such as iPads, tablets, and mobile phones and, probably, some of their lecturers used ICT tools during lectures.

However, some participants exhibited low mean scores in all three the knowledge domains. While these represented a small percentage, it raises concerns about the low confidence in their ICT competences. With these low scores, they are likely not to have high usage of ICT resources in their future classrooms. They are likely to adopt more traditional teacher-talk approaches of teaching which do not highly benefit the learner. Their scores could have been influenced by their views about technology and its use in teaching. To this effect, we interviewed a selected number of PST participants in relation to their views about teaching with ICTs. Their views are discussed in detail below.

Participants' views were summarized in terms of

(1) their views about pursuing the use of ICTs for teaching science,

(2) their views about teaching science using ICTs versus traditional teacher-talk,

(3) their views about challenges in using ICTs for teaching science, and

(4) their views about experiences with the use of ICTs for teaching science.

Regarding their *views about pursuing the use of ICTs for teaching science*, participants showed interest in teaching with ICTs in their future classes. The majority viewed ICTs as being important for effective teaching. They believed that pursuing ICTs was important for them to achieve the pedagogical objectives in their practice. Their intentions and beliefs in pursuing ICTs are considered the first and crucial step in ICT integration in their future classrooms. This is consistent with results of previous studies (Ertmer & Ottenbreit-Leftwich, 2010; Taimalu & Luik, 2019), which revealed that teacher views in instructional technology integration determined whether they would use ICTs in their classrooms or not.

Participants were very clear about their preference of teaching with ICTs as they expressed their *views about teaching science using ICTs versus traditional teacher-talk*. The majority felt that science would be meaningful to learners when taught using ICTs. This is consistent with the views of participants in a study by Sahal and Ozdemir (2020), where most of the participants indicated that they would use ICTs in their classrooms at every opportunity. They argued that videos during lessons would help learners conceptualize concepts by having visual representations. They also believed that ICTs would help them to be time efficient in class and that with many learners accessing mobile devices at home, ICTs can help capture the interest of learners in the subject. They also believe that pedagogical strategies that involve ICTs would enhance learner-centered classroom discourse. This is in tandem with the findings of a study conducted by Palak and Walls (2009). Palak and Walls (2009) encouraged professional development programs on ICT integration where PSTs would acquire skills in learner-centered pedagogy when teaching with ICTs. PSTs who participated in the current study viewed ICT to be educationally relevant and useful. These views agree with those of Cheng et al. (2021). However, some of PSTs in the current study felt that complementing ICTs with traditional teacher-talk would help consolidate a conceptual understanding among learners. They believed that some challenges that come with technology can be overcome by using traditional teacher-talk.

While majority of the participants were eager to pursue ICTs for teaching science and preferred teaching with ICTs versus traditional teacher-talk, their *views about challenges in using ICTs for teaching science* implied that their ICT integration would not be without challenges. They indicated that they did not have sufficient technological competence and experience to effectively teach with ICTs. They believed that this kind of competence was important, and they needed it for successful integration of ICTs into their lessons. This is consistent with findings of previous studies (Birisci & Kul, 2019; Keser et al., 2015) that technological competence would enhance PSTs' self-efficacy about ICT use and would determine whether they teach with ICTs or not. The implication of this result is that PSTs need to develop technological competence either by registering for ICT courses at university or through personal skills development.

It would also be helpful for teacher educators to develop compulsory courses for PSTs as part of their pedagogical courses. Regarding participants' *views about experiences with the use of ICTs for teaching science*, the majority had no experience teaching with ICTs. Those that reported using ICTs during teaching practice were limited to using videos downloaded from YouTube. Others reported using Microsoft Office tools such as Word, Excel, and PowerPoint. This lack of experience would impact negatively on their self-confidence to use ICTs in their classrooms. According to Bakac (2018), self-directed learning related to ICT usage would help PSTs acquire the needed experience to teach with ICTs. Teacher educators can use design practice (Moon et al., 2021) to help PSTs improve their beliefs about their capability to teach with ICTs. Some participants believed that teaching with ICTs would cause class management challenges, where it would be difficult to monitor each student to ensure that in cases where they are allowed to use the internet, they do not end up browsing from non-educational websites. While none of the participants reported this challenge, it would be good for schools to maintain manageable class sizes where the teacher-pupil ratio is not high. This is because class size has been reported in some studies as having an influence on teachers' use of ICTs in classrooms (Farjon et al., 2019; Ifinedo et al., 2020).

CONCLUSION

Teachers' acceptance, adoption, and integration of instructional technologies is influenced by several factors, including their views and knowledge about these educational technologies. This study focused on PSTs' knowledge and views about the integration of ICTs in science instruction in the SADC region. It is in this regional context that the study contributes to the field considering the limited research on the topic (Yesilyurt et al., 2016).

One of the important contributions of this study is its focus on PSTs' knowledge of TK, TCK, and TPK related to science teaching. Participants exhibited high TPK across all clusters, which demonstrates their confidence in using ICTs for teaching science and their perception of the educational value of ICTs in instruction (Baier & Kunter, 2020). While extensive research on the importance of TPACK in technology integration has been undertaken over the years, subject specific TCK and TPK have not received much attention (Chai et al., 2013; Graham, 2011; Knezek & Christensen, 2016; Yurdakul et al., 2012). In investigating PSTs' TK, TCK, and TPK, the current study emphasized the use of digital ICT resources for classroom instruction considering that previous studies focused more on technology integration using generic technological tools (see Yurdakul et al., 2012). Our focus on digital ICT resources is consistent with that of Chai et al. (2013), who emphasized the use of digital ICT resources for quality teaching.

One other key outcome of this study is that PSTs' ICT integration is dependent on their positive development of their views about ICTs and its educational value. For example, it would be difficult for PSTs to change from traditional teacher-talk pedagogical strategies to ICT-enriched strategies if they do not develop positive views about ICTs. This is because the change in views among teachers would likely result in change of behavior (Kagan, 1992; Kim et al., 2013; Ng et al., 2010).

The current study has also revealed that PSTs need to be supported in their development of positive views about ICTs during their teacher education programs as well as during their teaching practice. A good support system can boost their ICT integration (Kim et al., 2013). While majority of participants in the qualitative phase of this study expressed interest to pursue ICTs for teaching science, we are cognizant that not all of them will actualize their intentions if their views do not change.

This study was not without limitations. One of the limitations was the qualitative methodology we used. The implication of this methodology is that the results are limited to the sample that participated and can thus not be generalized to the whole SADC region. Notwithstanding the limitation, this study provides valuable results on which change can be enacted to improve PSTs' views about ICT integration. It is also a springboard on which several studies can be conducted. Overall, we conclude from the results that despite well-resourced ICT institutions, PSTs still underestimate their competences to teach science with ICTs. In addition, the majority believe that a different school environment and inadequate use of ICTs by themselves and their mentor teachers contribute to failure to build on their ICT competences.

Recommendations for Future Studies

Researchers in the SADC region should consider replicating this study in other countries in the region as a way of validating our findings. Future studies should also consider replication of the current study using both quantitative and qualitative methods by focusing exclusively on PSTs' TCK and TPK related to their impact on integration of specific mobile digital technologies (e.g., tablets) in classrooms. This will ensure a large sample and a rich data set which would provide depth and will also enable generalization of findings. As stated in the introduction, there is limited research focusing on PSTs' views about ICT integration (Yeşilyurt et al., 2016). Thus, researchers in the SADC region are encouraged to conduct robust studies on this topic to bridge the theoretical gap that has been caused by lack of research on the topic.

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